ARE INVERTEBRATE PEDESTRIANS THREATENED? OBSERVATIONS OF *HOPLOGONUS SIMSONI* FROM ROAD LINE TRANSECTS IN NORTHEASTERN TASMANIA

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INTRODUCTION

The Blue Tier region in northeast Tasmania is home to several flightless endemic stag beetle species. Due to their limited mobility some of these have restricted distributions and are considered narrow-range endemics. Five apterous lucanids are known to occur in the area, of which two, *Lissotes rudis* and *L. obtusatus*, have a saproxylic (log-dwelling) larval phase, while the remaining three, *Hoplogonus simsoni*, *H. bornemisszai* and *H. vanderschoori* each have edaphic (soil-dwelling) larvae.

Hoplogonus simsoni Parry, 1875 (Plate 1) is the largest and most widespread of the three species of Hoplogonus and is listed as vulnerable on both the Tasmanian *Threatened Species Protection Act 1995* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, due to its restricted distribution (265 km²) and the on-going threats to the habitat in which it occurs. Two other more widely distributed apterous lucanidae occur sympatrically with *H. simsoni*. *Lissotes rudis* Lea, 1910 is patchily distributed across the north of the State: its peak density falls within the geographic range of *H. simsoni*. *Lissotes obtusatus* Westwood, 1838 is more widespread, occurring over the majority of the State. *H. simsoni* is the most intensively studied lucanid in the region; nonetheless there remains an information deficit concerning the response of the species to some perceived threatening processes (TSS 2012).

Estimates of the population abundance of *H. simsoni* vary widely, from in excess of 10,000 (Meggs 1997) to approximately 40 million (Fox et al. 2004). Recognised threats to the population include habitat loss or modification, removal of forest canopy, bushfires, climate change, predation and illegal collection (TSS 2012), while another "perceived" threat may be from road traffic (G. Bornemissza pers. comm. 2007). Understanding the true nature of such impacts is important for recovery of the species. However, in the case of the impact of road traffic, it remains to be verified if this is indeed a threat to the population.

Factors such as terrestrial locomotion, longevity and predation limit dispersal ability of apterous lucanid beetles. This may be further compounded by environmental influences including changes in altitude, geology and soil composition or soil moisture levels, as demonstrated for *H. simsoni* by Meggs et al. (2003, 2004). It has previously been speculated that the dispersal capability of *H. simsoni* may be limited to as little as 100-200 metres in a lifetime (G. Bornemissza and P. McQuillan pers. comm., cited in Meggs et al. (2003)), and that the dispersal speed of *Hoplogonus* is greatly influenced by temperature conditions at ground level (G. Bornemissza pers. comm.). Bornemissza predicts that an increase of 5°C at ground level initiates a doubling of travelling speed from 2-3 m/min to 6-8m/min; however, there is currently no data supporting these claims.

Plate 1. Live adult male *Hoplogonus simsoni*

Plate 2. Road fatalities of *Hoplogonus simsoni*

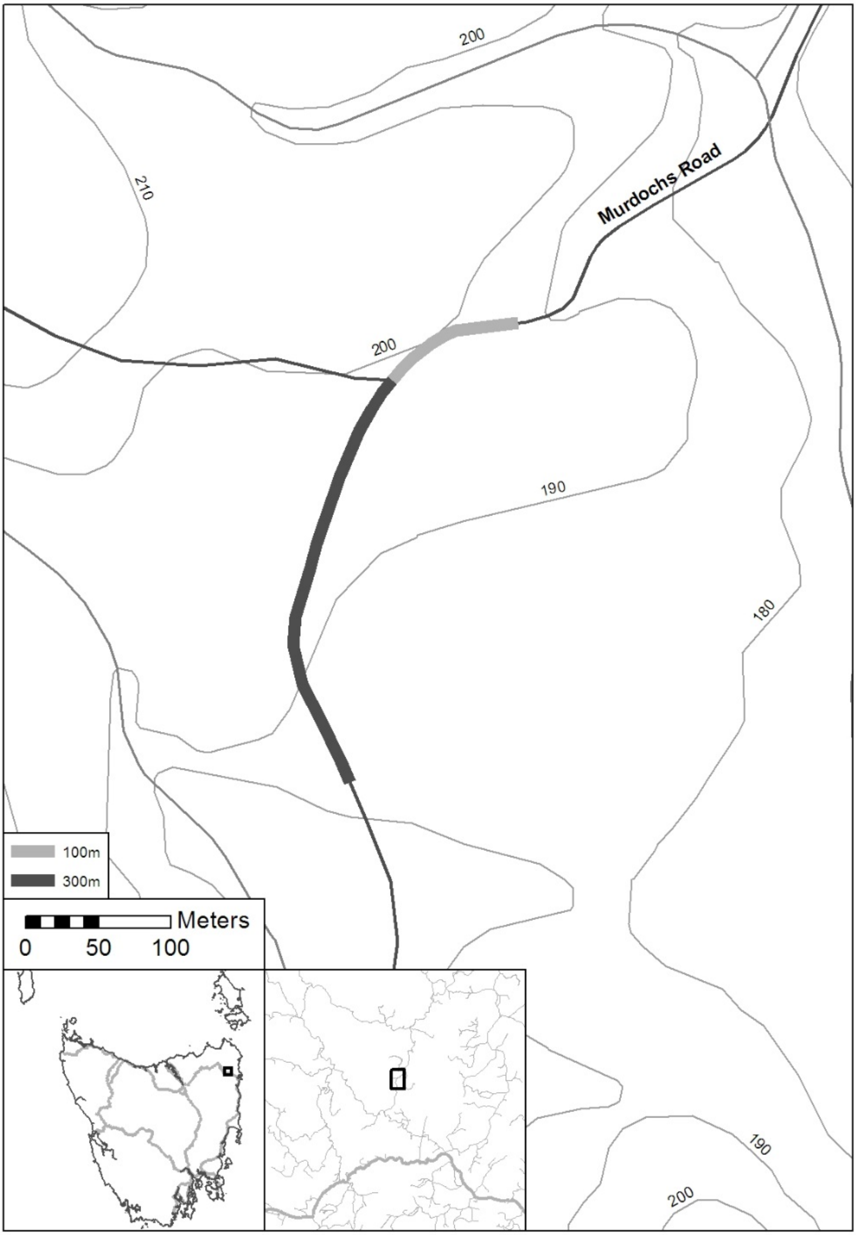


Figure 1. Study sites along Murdochs Road, northeastern Tasmania

Research is required to determine the extent and dispersal speed of members of the Tasmanian Lucanidae.

Studies on the dispersal capability of the brachypterous European lucanid *Lucanus cervus* established that on average males disperse 802 m, while female flight is limited, travelling an average 263 m (Rink et al. 2011). Death from road traffic has been recognised as a threatening process for *L. cervus* across Europe, impacting females more than males due to their preferred mechanism of travel, spending a greater proportion of time on the ground looking for oviposition sites (Hawes 2008, cited in Harvey et al. 2011a). Using road transect surveys, Harvey et al. (2011 a,b) investigating monitoring methods and distribution of *L. cervus*, established that road death was a contributing factor in the decline of some populations.

To date, the use of road transect surveys as a technique to monitor invertebrate populations has been infrequently reported in the literature. Hayward et al. (2010) used road surveys to determine the impact of road surface upgrades on dung beetle fatality, whilst Noordijk et al. (2006) applied mark-recapture techniques to illustrate the influence of roads on carabid beetle movement. Regurgitated remains on roadways have also been utilised as a means of monitoring beetle species presence (Campanaro et al. 2011). Additionally, Harvey et al. (2011b) alludes to a number of unpublished accounts, pertaining to road kill monitoring of *L. cervus*, from several European countries.

Published studies on road death impacts in Tasmania using road transect survey methods appear restricted to vertebrate fauna (e.g. Mooney & Spencer 1999; Jones 2000; Hobday & Minstrell 2008; Taylor & Goldingay 2010). While it has been suggested that road death is a potential threat to *H. simsoni*, the degree of impact remains unknown. In January 2007, we initiated a study to examine the mortality rates of lucanid beetles on a forest road in an area predicted to contain a high population density of *H. simsoni* (Meggs et. al 2004). The study records a fortnightly snapshot of lucanid numbers on the roadway (Plate 2), identifying species, sex and survival status.

METHODS

Study area

The study was conducted on Murdochs Road, at Goulds Country, near the Blue Tier in northeast Tasmania (Figure 1). The study area is located between 185-200 m a.s.l. and is subjected to relatively high annual rainfall (1200 mm) much of which occurs intermittently as heavy downpours associated with persistent low-pressure systems over the Tasman Sea (Mesibov 1988). Sites were bounded by wet sclerophyll forest containing a mixture of mature (unharvested) and regrowth *Eucalyptus regnans*, with an understorey of wet forest species including *Acacia dealbata*, *A. melanoxylon*, *Olearia lirata*, *O. argophylla*, *Pittosporum bicolor*, *Pomaderris apetala*, *Zieria arborescens*, *Cassinia trinerva*, *Atherosperma moschatum* and *Dicksonia antarctica*. Due to periodic slashing, the road verges support few trees, but are densely vegetated by a range of low-growing fern species, including *Blechnum nudum*, *B. wattsii*, *Histiopteris incisa*, *Polystichum proliferum* and *Pteridium esculentum*.

Transect design

Transect sites were located in an area predicted to support a high population density of *H. simsoni*, identified using the habitat model developed by Meggs et al. (2004) and selected based on accessibility. Two transects, each including a mosaic of differing levels of shade and sun exposure were chosen: transect T1 (Plate 3), commenced at 588504mE 5435824mN and was 100 m long; transect T2 (Plate 4), commenced at 588419mE 5435699mN and was 300 m long (Figure 1).

Survey methods

Surveys were undertaken at fortnightly intervals from September to April between July 2007 and May 2011, encompassing the period over which *H. simsoni* imagines (adults) were active each season. To encompass the entire active period of *H. simsoni*, surveys were initiated 1 month prior to the onset of the activity season (G. Bornemissza pers. comm.) and continued for 1 month after the cessation of beetle activity.

Established January 2007, T1 was surveyed a total of 66 occasions, while T2 was initiated January 2008 and surveyed on 39 occasions. Two researchers walked each transect in both directions at fortnightly intervals recording beetle presence. The 30-minute survey (transects combined) was undertaken between 0930-1200h; additional inspections were periodically conducted at different times of the day and evening to establish activity patterns of *H. simsoni* across a range of weather and light conditions.

Data collected

On each survey, all living and dead Lucanidae (species of *Hoplogonus* and *Lissotes*), excluding remains from scats and pellets, were collected, the species identified, sexed and counted. All beetle remains, including those contained in scat and pellet material were removed from the road surface to preclude subsequent multiple recording. Live lucanids were released into the adjoining forested area immediately after processing. Specimens crushed by vehicular traffic were often dismembered, therefore only head capsules of disarticulated beetles were included in the count.

The dispersal speeds of individual *H. simsoni* were recorded opportunistically, *in situ* on the road surface, whenever active beetles were encountered. Each beetle's movements were closely followed and progress, including directional changes, marked on the road surface. Measurements of the distance travelled were recorded at 60 second intervals over a 5 minute period and an average dispersal speed of individuals calculated.

Observations of cloud cover (%) and prevailing weather conditions were recorded at each survey and traffic volumes noted.

RESULTS

A total of 503 *H. simsoni* were recorded on the roadway during this study, 117 from T1 (30 live, 87 dead) and 386 from T2 (65 live, 321 dead), with a seasonal average of 29 (T1) and 128 (T2). Over the four years of this study, the proportion of males to females was similar across individual transects (63 male: 54 female (T1); 202 male: 184 female (T2)) for both live and dead individuals. *Lissotes rudis* occurred in lower overall densities: a total of 36, consisting of 17 live (10 (T1), 7 (T2)) and 19 dead beetles (5 (T1), 14 (T2)) were recorded across the survey period. No *L. obtusatus* were found.

For disarticulated specimens, only head capsules were included in the count. This resulted in an underestimate of total beetles recorded, as the head capsules of some specimens could not be located; however, this was applicable in only a few instances.

Dead specimens constituted the greatest proportion of *H. simsoni* recorded over the survey period, the percentages of which ranged from 73% (T1) to 84% (T2). Crushed beetles represented 48-53% of total beetles recorded at each transect, while the proportion of males to females was similar within each transect (T1 73-76%;

Plate 3. View along Transect 1 – looking north

Plate 4. View along Transect 2 – looking south

T2: 84-83%, male to female, respectively). Despite variations in total beetle numbers per activity season, these patterns remained consistent throughout the survey period.

The average number of *H. simsoni* recorded differed between transects: 1.77 beetles per survey (T1), 9.9 beetles per survey (T2). It should be noted, however, that these figures include many negative results, particularly on T1, as well as the surveys prior to and at the cessation of the beetle activity period; they also reflect the difference in transect length. The maximum number of males collected in a single survey was 37 (T2); whereas for females the number was lower, at 24 (T2). Live animals contributed only a small proportion of the total per survey and were infrequently encountered, occurring on less than 20% of survey events. The maximum number of live beetles recorded for an individual survey was 6 males (13/11/09) and 5 females (8/1/08), both from T2.

Seasonal variation in beetle numbers occurred, with the 2009/10 active period recording the greatest overall numbers (Table 1).

Table 1. Beetle numbers recorded from transects T1 & T2, by activity season

Transect	Year	Female	Male	Total
T1	2007*	12	11	23
T1	2007/08	18	21	39
T1	2008/09	11	14	25
T1	2009/10	13	17	30
Totals T1		**54**	**63**	**117**
T2	2008*	65	35	100
T2	2008/09	41	83	124
T2	2009/10	78	84	162
Totals T2		**184**	**202**	**386**
Totals		**238**	**265**	**503**

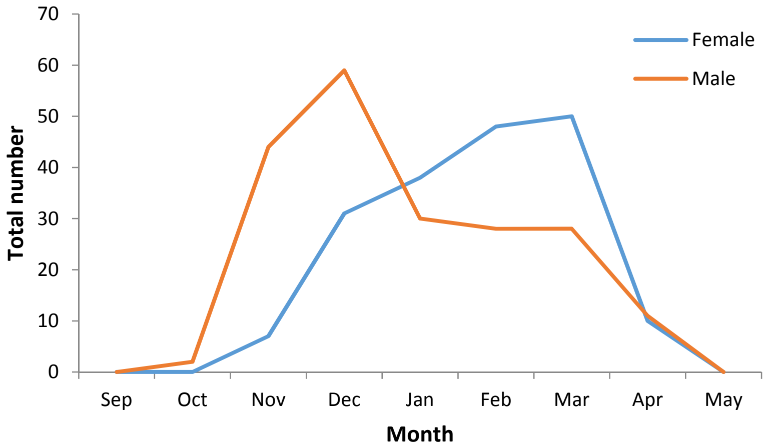
* values for T1 2007 and T2 2008 represent beetles collected over a partial active season (Jan.−Apr.)

The activity period of *H. simsoni* was consistently between mid October to late April throughout the study period. While the sexes were evenly represented across the active season, the peak active period differed between sexes, males becoming active early in the season, peaking in December, and female activity commencing later, reaching maximum abundance in February (Figure 2).

Observations of beetle activity patterns indicated a crepuscular preference, however, *H. simsoni* imagines were found to be active throughout the daylight hours. Evening surveys conducted on the transects revealed reduced numbers of lucanid beetles in receding light and activity ceasing with the onset of darkness. Both *H. simsoni* and *L. rudis* were observed to be inactive during, and subsequent to, periods of heavy rainfall.

A number of non-target invertebrate animals were encountered on the transects. Most often observed were ants, mostly

Myrmecia pilosula, however, *M. forficata* and *M. esuriens* were regulars; species of *Iridomyrmex* were constantly present. Invertebrates occasionally recorded included the grasshopper *Gastrimargus musicus*, beetles *Coripera deplanata*, *Adelium licinoides* and *Notonomus politulus*, the scorpion *Cercophonius squama*, snails *Caryodes dufresnii* and *Helicarion cuvierii*, the sawfly *Perga affinis*, and the emperor gum moth *Opodipthera helena*.



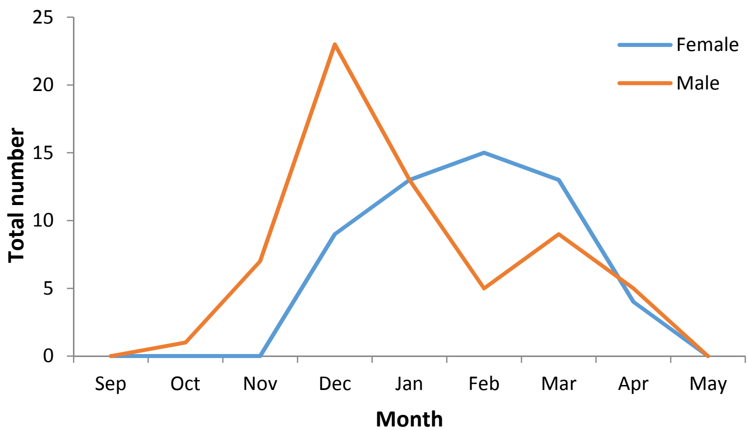


Figure 2. Activity patterns of male and female *H. simsoni* (seasonal data combined): top = transect 1; bottom = transect 2

Predation on Hoplogonus *species*

Dasyurid scats and regurgitated pellets produced by corvid species collected from the road transects were at times found to contain exoskeletal material of *H. simsoni*. Scat evidence (Plate 5) revealed that *Dasyurus maculatus* (spotted-tailed quoll) and *D. viverrinus* (eastern quoll) predate *H. simsoni* imagines in similar quantity, with an increased frequency early in the beetles' activity period. While *Sarcophilus harrisii* (Tasmanian devil) also consume *H. simsoni*, the number of exoskeletal remains present in scats was much reduced and found to be more often contained in smaller scats.

Three corvid species are known to occur in the study area, regurgitated material from two, *Strepera fuliginosa* (black currawong) and *Corvus tasmanicus* (forest raven) were present on the transects and both often contained fragments of multiple *H. simsoni*, the remains of 12 males being the highest number recovered from a single pellet (Plate 6). Though not recorded in the current study, *Potorous tridactylus* (potoroo), *Tachyglossus aculeatus (echidna)*, *Strepera versicolor* (grey currawong) and *Dacelo novaeguinea* (kookaburra) have also been observed to predate *Hoplogonus* species (Spencer & Richards unpubl. data).

Travelling speed

H. simsoni males recorded faster locomotion than females, averaging 45.0 cm/min compared to 26.5 cm/min for females. The maximum speeds obtained were 75 cm/min (male) and 42 cm/min (female). Given these figures, we estimate that, travelling at average speeds, a male *H. simsoni* crossing the road in a straight line perpendicular to the road edge would take 7.7 minutes and a female 13.4 minutes. It should be noted, however, that *H. simsoni* locomotion is seldom constant, progress often being punctuated with lengthy pauses, directional changes and beetles rarely attempting to cross the road in a perpendicular fashion. The rate of *H. simsoni* locomotion was not found to correlate to time of day, percentage canopy cover, cloud cover or air temperature.

DISCUSSION

Murdochs Road is a narrow winding forestry road carrying infrequent traffic, generally consisting of forest industry employees and occasional tourists. No timber harvesting or quarrying operations travelling this route were active during the study period, the only regular traffic being transport to and from a fire tower accessed from a side road. Consequently, only infrequent, light traffic was recorded using the thoroughfare. It is estimated that a maximum number of five vehicles per day travelled the road in peak periods.

The activity patterns observed for *H. simsoni* coincided with data collected from a concurrent pit-fall trapping study in adjacent forest (Spencer & Richards unpubl. data), supporting that the road transect data is representative of the behaviour of the species over the greater area. Data for *L. rudis* recorded over the same period suggest that this species occurs in lower numbers, a result also supported by data from the pitfall study.

While some beetle mortality can be attributed to traffic on Murdochs Road, vehicular use of the road was limited and death from unknown causes explained greater than 50% of the dead beetle count. The remaining corpses consisted of crushed specimens, however, for many it was not possible to ascertain the nature of death i.e. those that were killed directly by vehicles or, having died of unknown causes, were subsequently crushed by traffic.

The data for *H. simsoni* revealed a difference in peak activity for the sexes.

Plate 5. Scat of *Dasyurus maculatus* (spotted-tailed quoll) containing exoskeletal material from *H. simsoni*

Plate 6. Pellet of *Strepera fuliginosa* (black currawong) containing exoskeletal material from *H. simsoni*

L. rudis exhibited no such peaks, although this may not have been discernible due to the low number of individuals recorded in any survey event. Harvey et al. (2011a) observed a road death sex bias towards female *L. cervus*, shown to be due to dispersal mode. Such a pattern was not detected in *H. simsoni*.

This study targeted lucanid beetles, principally *H. simsoni*. However, many other invertebrate animals were encountered as corpses, accidental arrivals or healthy individuals in transit. The living were relocated to more suitable environments whenever possible, but for some, the roadway had become a foraging ground where food and construction materials were in abundant supply. Though found only once in adult form, *Perga affinis* (sawfly) were often located as single larvae that had fallen from the tree canopy, as was the case for the spectacular *Opodipthera helena* (emperor gum moth).

Lucanid beetles are somewhat slow and cumbersome, with fossorial forelegs designed for excavating and moving through decaying organic matter or soil, not swift locomotion. The maximum speeds documented in this study for either sex of *H. simsoni* were rarely achieved and fall well short of the predictions made by G. Bornemissza. Rather than increasing speed when disturbed, as has been demonstrated in carabid studies (e.g. Kamoun & Hogenhout 1996), *H. simsoni* imagines exhibit immediate thanatosis (feigning death) when threatened by looming shadows or sensing ground vibration. Such behavioural traits in *H. simsoni* may contribute to the likelihood of predation or road fatality.

The current study found no evidence to support temperature having any influence on the locomotion of *H. simsoni*. The species displayed diurnal activity patterns and light intensity appeared to not impact the species, with active beetles observed throughout the daylight hours. Rainfall events throughout the survey period, however, did impact on beetle activity and consequently, the findings of this study. Rainfall volume and intensity differed between sampling seasons and was frequent but inconsistent. These events impacted greatly on the number of beetles located on the road surface as leaf litter debris was often removed when torrential rain transformed the road surface into a series of streams, leaving the surface scoured and channelled with mounds of accumulated debris in deposition zones.

The degree to which predators and scavengers used the thoroughfare was evident by the scats and regurgitated pellets frequently recorded when clearing transects. While the impact of predation on the number of lucanid beetles recorded could not be ascertained, exoskeletal remains of Lucanidae were often visible in the animal waste present. It is likely that a proportion of the beetles transiting the roadway became prey and therefore our data is an underestimate of the total beetle count. Despite the lack of nocturnal behaviour exhibited by *H. simsoni*, the species is seasonally included in the dasyurid diet. Explanations for this relate to the hunting and scavenging habits of the dasyurids and the propensity for a level of diurnal activity exhibited by these animals. Imagines and larvae of *H. simsoni* are to be found beneath decaying logs and in the upper soil horizon making them easily accessible to predators: the roadkill component could be seen as food without effort.

CONCLUSION

Estimating the impact of road deaths on the population of *H. simsoni* was not the aim of this research. Rather, it was conducted to provide base line data on beetle mortality and dispersal across a forest thoroughfare.

While a large number of *H. simsoni* imagines as well as a range of other invertebrate species were shown to be active and at times killed on roadways, we do not suggest that mortality rates are significantly greater than in the adjoining forest where litter accumulations conceal invertebrate deaths. The application of road transect survey methods for invertebrate research may be especially useful to provide basic information on invertebrate movement and mortality rates. Further, such methods offer a simple but effective means of gathering data on population dynamics and potential impacts of roads and traffic on invertebrate dispersal.

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